SILECS/Grid'5000: le volet data-center de SILECS : Présentation et exemples d'expériences

Lucas Nussbaum

SILECS/Grid'5000

Le volet data-center de SILECS

Présentation et exemples d'expériences

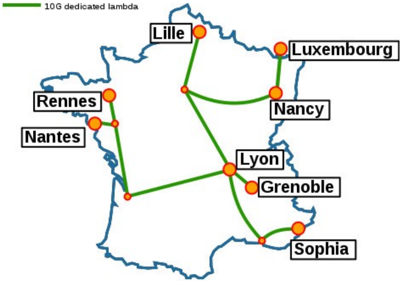
Lucas Nussbaum

Grid'5000 Technical Director

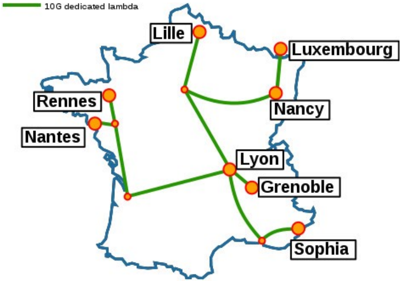
Workshop TILECS
2019-07-03

The Grid’5000 testbed

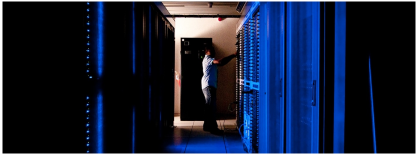
- **A large-scale testbed for distributed computing**
  - 8 sites, 31 clusters, 828 nodes, 12328 cores
  - Dedicated 10-Gbps backbone network
  - 550 users and 120 publications per year



The Grid'5000 testbed



- **A large-scale testbed for distributed computing**
  - 8 sites, 31 clusters, 828 nodes, 12328 cores
  - Dedicated 10-Gbps backbone network
  - 550 users and 120 publications per year
- **A meta-cloud, meta-cluster, meta-data-center**
  - Used by CS researchers in HPC, Clouds, Big Data, Networking, AI
  - To experiment in a fully controllable and observable environment
  - Similar problem space as Chameleon and Cloudlab (US)
  - Design goals
    - Support high-quality, reproducible experiments
    - On a large-scale, distributed, shared infrastructure



Landscape – cloud & experimentation[1]

- Public cloud infrastructures (AWS, Azure, Google Cloud Platform, etc.)
  - ☹ No information/guarantees on placement, multi-tenancy, real performance
- Private clouds: Shared observable infrastructures
  - ☺ Monitoring & measurement
  - ⇝ Ability to understand experiment results
  - ☹ No control over infrastructure settings
- Bare-metal as a service, fully reconfigurable infrastructure (Grid'5000)
  - ☺ Control/alter all layers (virtualization technology, OS, networking)
  - ⇝ *In vitro* Cloud

And the same applies to all other environments (e.g. HPC)

[1] Inspired from a slide by Kate Keahey (Argonne National Lab)

Some recent results from Grid'5000 users

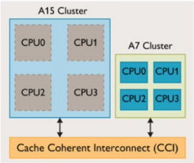
- Portable Online Prediction of Network Utilization (Inria Bdx + US)
- Energy proportionality on hybrid architectures (LIP/IRISA/Inria)
- Damaris: scalable, asynchronous data storage for large-scale simulations (Inria)
- Toward a resource management system for Fog/Edge infrastructures

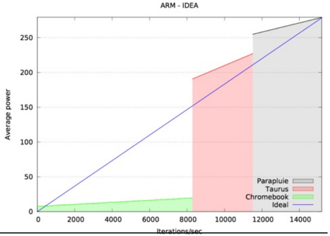
Portable Online Prediction of Network Utilization

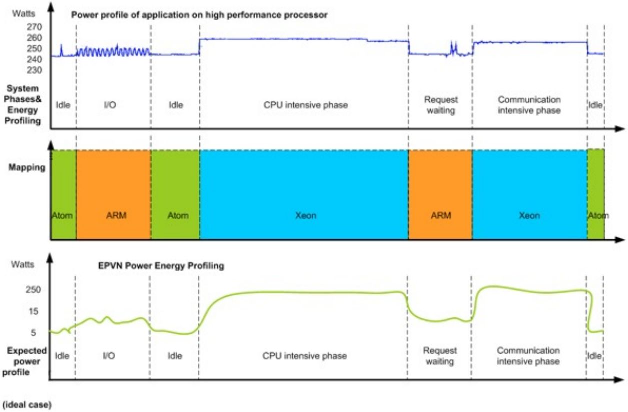
- **Problem**
  - Predict network utilization in near future to enable optimal utilization of spare bandwidth for low-priority asynchronous jobs co-located with an HPC application
- **Goals**
  - High accuracy, low compute overhead, learn on-the-fly without previous knowledge
- **Proposed solution**
  - Dynamic sequence-to-sequence recurrent neural networks that learn using a sliding window approach over recent history
  - Evaluate the gain of a tree-based meta-data management
  - INRIA, The Univ. of Tennessee, Exascale Comp. Proj., UC Irvine, Argonne Nat. Lab.
- **Grid'5000 experiments**
  - Monitor and predict network utilization for two HPC applications at small scale (30 nodes)
  - Easy customization of environment for rapid prototyping and validation of ideas (in particular, custom MPI version with monitoring support)
  - Impact: Early results facilitated by Grid'5000 are promising and motivate larger scale experiments on leadership class machines (Theta@Argonne)

Energy proportionality on hybrid architectures[2]

- Hybrid computing architectures : low power processors, co processors, GPUs. . .
- Supporting a “Big, Medium, Little” approach : the right processor at the right time



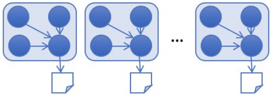




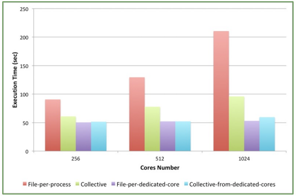
[2] V. Villebonnet, G. Da Costa, L. Lefèvre, J.-M. Pierson and P. Stolf. "Big, Medium, Little" : Reaching Energy Proportionality with Heterogeneous Computing Scheduler", Parallel Processing Letters, 25 (3), Sep. 2015

Damaris
Scalable, asynchronous data storage for large-scale simulations using the HDF5 format

- **Traditional approach**
  - All simulation processes (10K+) write on disk at the same time synchronously
  - Problems: 1) I/O jitter, 2) long I/O phase, 3) Blocked simulation during data writing
- **Solution**
  - Aggregate data in dedicated cores using shared memory and write asynchronously

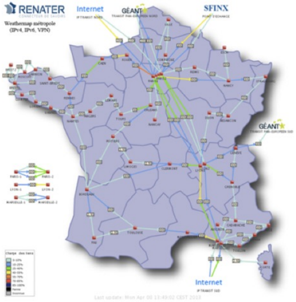


- **Grid'5000 used as a testbed**
  - Access to many (1024) homogeneous cores
  - Customizable environment and tools
  - Repeat the experiments later with the same environment saved as an image
  - The results show that Damaris can provide a jitter-free and wait-free data storage mechanism
  - G5K helped prepare Damaris for deployment on top supercomputers (Titan, Pangea (Total), Jaguar, Kraken, etc.)
  - https://project.inria.fr/damaris/



Toward a resource management system for Fog/Edge infras.

- **Inria Project Lab: Discovery**
  - Design a resource management system (a.k.a. a cloudkit) for Fog/Edge infrastructures
  - A four year project started in 2015 with Inria, Orange (and initially Renater)
  - Designing from scratch such a system cannot be envisioned (OpenStack 13 Millions of LOCs)
- **Contributions**
  - Implementation of a complete workflow to evaluate OpenStack WANWide scenarios
  - Evaluate OpenStack up to 1000 compute nodes (Grid’5000, oct 2016)
  - Evaluate OpenStack WANWide (impact of latency and throughput constraints) (oct 2017)
  - Evaluation of communication bus for Fog/Edge scenarios (May 2018)
  - Evaluation of database backends (NewSQL, NoSQL, etc. (May 2018)



Deploy a micro DC on each Network Point of Presence

Multi-Level Elasticity for Data Stream Processing

Vania Marangozova-Martin, Noël de Palma and Ahmed El Rheddane
Univ. Grenoble Alpes, CNRS, LIG, F-38000 Grenoble France
E-mail: firstName.secondName@imag.fr

Abstract—This paper investigates reactive elasticity in stream processing environments where the performance goal large amounts of data with low latency and minimum resources. Working in the context of Apache Storm, we propose management strategy which modulates the parallelism degree of applications' components while explicitly addressing execution containers (virtual machines, processes and threads). We show that provisioning the wrong kind of containe performance degradation and propose a solution that provisions the least expensive container (with minimum resourc performance. We describe our monitoring metrics and show how we take into account the specifics of an execution er provide an experimental evaluation with real-world applications which validates the applicability of our approach.

Index Terms—stream processing, multi-level elasticity, Apache Storm

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/TPDS.2019.2907950, IEEE Transactions on Parallel and Distributed Systems

would need to be deployed in containers with different capacities which in turn call for multi-dimensional-bin-packing-oriented scheduling [45].

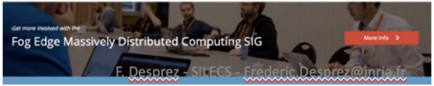
ACKNOWLEDGEMENTS

The experimental work presented in this paper would not have been possible without the existence of the Grid’5000 platform and the help of the supporting teams. The authors would also like to thank the *enos* team who made the Openstack deployment process a child’s play.

[18] “CoMD,” https://gpuopen.com/compute-product/comd/.
[19] Y. Wu and K. L. Tan, “ChronoStream: Elastic Stateful Stream Computation in the Cloud,” in *2015 IEEE 31st International Conference on Data Engineering*, April 2015, pp. 723–734.
[20] V. Gulisano, R. Jimenez-Peris, M. Patino-Martinez, C. Soriente, and P. Valduriez, “StreamCloud: An Elastic and Scalable Data Streaming System,” *IEEE Trans. Parallel Distrib. Syst.*, vol. 23, no. 12, pp. 2351–2365, Dec. 2012.
[21] L. Neumeyer, B. Robbins, A. Nair, and A. Kesari, “S4: Distributed stream computing platform,” in *Data Mining Workshops (ICDMW), 2010 IEEE International Conference on.* IEEE, 2010, pp. 170–177.
[22] OpenStack. https://www.openstack.org/.
[23] “Grid’5000,” http://www.grid5000.fr/.
[24] R. Cherrueau, D. Pertin, A. Simonet, A. Lebre, and M. Simonin, “Toward a Holistic Framework for Conducting Scientific Evalua-

Toward a resource management system for Fog/Edge infras.

- **Inria Project Lab: Discovery (contd)**
  - The creation of a dedicated working group within the OpenStack community that deals with Fog/Edge challenges (now managed by the foundation with key actors such as ATT, Verizon, CISCO, China mobile etc.)
  - Several presentations / publications (see the DISCOVERY website)
  - France has the main academic actor in the worldwide community (Inria/IMT Atlantique) thanks to the G5K testbed in particular.
    - A leadership position
    - A strong expertise for experiments related to performance, scalability of OpenStack components (concrete actions with RedHat, ongoing actions with Huawei, etc.)



Open Infrastructure summit
Vancouver May 2018
(3000 participants)

An experiment's outline

1. Discovering resources and selecting resources
2. Reconfiguring the resources to meet experimental needs
3. Monitoring experiments, extracting and analyzing data
4. Controlling experiments $\leadsto$ automation, reproducible research

Discovering and selecting resources

- Describing resources $\leadsto$ understand results
  - Covering nodes and network infrastructure
  - Machine-parsable format $\leadsto$ scripts
  - Human-readable description on the web[3]
  - Archived (*State of testbed 6 months ago?*)
  - Verified
    - Avoid inaccuracies/errors $\leadsto$ wrong results
    - Self-checking by nodes before each reservation


```
"processor": {
  "cache_l2": 8388608,
  "cache_l1": null,
  "model": "Intel Xeon",
  "instruction_set": "",
  "other_description": "",
  "version": "X3440",
  "vendor": "Intel",
  "cache_l1i": null,
  "cache_l1d": null,
  "clock_speed": 2530000000.0
},
"uid": "graphene-1",
"type": "node",
"architecture": {
  "platform_type": "x86_64",
  "smt_size": 4,
  "smp_size": 1
},
"main_memory": {
  "ram_size": 17179869184,
  "virtual_size": null
},
"storage_devices": [
  {
    "model": "Hitachi HDS72103",
    "size": 298023223876.953,
    "driver": "ahci",
    "interface": "SATA II",
    "rev": "JPFO",
    "device": "sda"
  }
],
```


- Selecting resources
  - Complex queries using resource manager

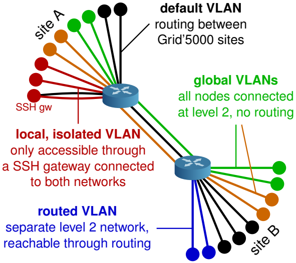
```
oarsub -p "wattmeter='YES' and gpu='YES'"
oarsub -l "{cluster='a'}/nodes=1+
 {cluster='b' and eth10g='Y'}/nodes=2"
```

Site	Cluster	Queue	Date of arrival	Nodes	CPU	Cores	Memory	Storage	Network	Accelerators
Grenoble	dahu	default	2018-03-22	32	2 x Intel Xeon Gold 6130	16 cores/CPU	192 GiB	240 GB SSD + 480 GB SSD + 4.0 TB HDD	10 Gbps + 100 Gbps Omni-Path	
Grenoble	yeti	default	2018-01-16	4	4 x Intel Xeon Gold 6130	16 cores/CPU	768 GiB	480 GB SSD + 2 x 1.6 TB SSD + 3 x 2.0 TB HDD	10 Gbps + 100 Gbps Omni-Path	
Lille	chetemi	default	2016-12-01	15	2 x Intel Xeon E5-2630 v4	10 cores/CPU	256 GiB	2 x 300 GB HDD	2 x 10 Gbps	
Lille	chiclet	default	2018-08-06	8	2 x AMD EPYC 7301	16 cores/CPU	128 GiB	480 GB SSD + 2 x 4.0 TB HDD	2 x 25 Gbps	
Lille	chifflet	default	2016-12-01	8	2 x Intel Xeon E5-2680 v4	14 cores/CPU	768 GiB	2 x 400 GB SSD + 2 x 4.0 TB HDD	2 x 10 Gbps	2 x Nvidia GTX 1080 Ti
Lille	chifflot	default	2018-08-01	8	2 x Intel Xeon Gold 6126	12 cores/CPU	192 GiB	2 x 480 GB SSD + 4 x 4.0 TB HDD	2 x 25 Gbps	[1-6]: 2 x Nvidia Tesla P100 [7-8]: 2 x Nvidia Tesla V100
Luxembourg	granduc	default	2011-12-01	11	2 x Intel Xeon L5335	4 cores/CPU	16 GiB	146 GB HDD	2 x 1 Gbps + 10 Gbps	
Luxembourg	petitprince	default	2013-09-10	15	2 x Intel Xeon E5-2630L	6 cores/CPU	32 GiB	250 GB HDD	2 x 10 Gbps	
Lyon	hercule	default	2012-10-02	4	2 x Intel Xeon E5-2620	6 cores/CPU	32 GiB	3 x 2.0 TB HDD	10 Gbps	
Lyon	nova	default	2016-12-01	23	2 x Intel Xeon E5-2620 v4	8 cores/CPU	64 GiB	598 GB HDD	10 Gbps	
Lyon	orion	default	2012-09-14	4	2 x Intel Xeon E5-2630	6 cores/CPU	32 GiB	598 GB HDD	10 Gbps	Nvidia Tesla M2075
Lyon	sagittaire	default	2006-07-01	32	2 x AMD Opteron 250	1 core/CPU	2 GiB	73 GB HDD	1 Gbps	
Lyon	taurus	default	2012-09-14	14	2 x Intel Xeon E5-2630	6 cores/CPU	32 GiB	598 GB HDD	10 Gbps	
Nancy	graoully	production	2016-01-04	16	2 x Intel Xeon E5-2630 v3	8 cores/CPU	128 GiB	2 x 600 GB HDD	10 Gbps + 56 Gbps InfiniBand	
Nancy	graphique	production	2015-05-12	6	2 x Intel Xeon E5-2620 v3	6 cores/CPU	64 GiB	299 GB HDD	10 Gbps + 56 Gbps InfiniBand	1: 2 x Nvidia Titan Black [2-6]: 2 x Nvidia GTX 980
Nancy	graphite	default	2013-12-05	4	2 x Intel Xeon E5-2650	8 cores/CPU	256 GiB	2 x 300 GB SSD	10 Gbps + 56 Gbps InfiniBand	Intel Xeon Phi 7120P
Nancy	grcinq	production	2013-04-09	48	2 x Intel Xeon E5-2650	8 cores/CPU	64 GiB	1.0 TB HDD	1 Gbps + 56 Gbps InfiniBand	
Nancy	grele	production	2017-06-26	14	2 x Intel Xeon E5-2650 v4	12 cores/CPU	128 GiB	2 x 299 GB HDD	10 Gbps + 100 Gbps Omni-Path	2 x Nvidia GTX 1080 Ti
Nancy	grimani	production	2016-08-30	6	2 x Intel Xeon E5-2603 v3	6 cores/CPU	64 GiB	1.0 TB HDD	10 Gbps + 100 Gbps Omni-Path	2 x Nvidia Tesla K40M
Nancy	grimoire	default	2016-01-22	8	2 x Intel Xeon E5-2630 v3	8 cores/CPU	128 GiB	200 GB SSD + 5 x 600 GB HDD	4 x 10 Gbps + 56 Gbps InfiniBand	
									[1-48]: 1 Gbps + 4 x 10 Gbps	

[3] https://www.grid5000.fr/w/Hardware

Reconfiguring resources

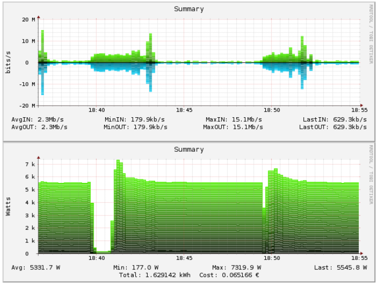
- Operating System reconfiguration with Kadeploy:
  - Provides a *Hardware-as-a-Service* cloud infrastructure
  - Enable users to deploy their own software stack & get *root* access
  - **Scalable, efficient, reliable and flexible**:
    200 nodes deployed in ~5 minutes
- Customize networking environment with KaVLAN
  - Protect the testbed from experiments (Grid/Cloud middlewares)
  - Avoid network pollution
  - Create custom topologies
  - By reconfiguring VLANS $\rightsquigarrow$ almost no overhead



Monitoring experiments

Goal: enable users to understand what happens during their experiment

- System-level probes (usage of CPU, memory, disk, with Ganglia)
- Infrastructure-level probes: Kwapi
  - Power consumption, (Network trafic)
  - Captured at high frequency (≈1 Hz)
  - Live visualization
  - REST API
  - Long-term storage



Controlling experiments

- Legacy way of performing experiments: shell commands
  - ☹ time-consuming
  - ☹ error-prone
  - ☹ details tend to be forgotten over time
- Promising solution: **automation of experiments**
  - ⇝ Executable description of experiments
  - ⇝ Reproducible research
- Support from the testbed: Grid'5000 RESTful API
  (Resource selection, reservation, deployment, monitoring)
- Several higher-level tools to help automate experiments
  Execo, Python-Grid5000 (Python), Ruby-cute (Ruby)

`https://www.grid5000.fr/w/Grid5000:Software`

Other features and services

- Flexible usage rules: *default* vs *production* (long jobs) vs *besteffort* (background)
- Data storage (group storage, disk reservation)
- Reproducible system images for Debian 8, 9, 10 (soon), *testing*; Centos 7, Ubuntu 18.04
- *sudo-g5k* to get root priviledges on the standard environment
- To be announced soon:
  - Network-level federation with Fed4FIRE testbeds
  - 10 Gb connection to the Internet
- Work in progress:
  - New clusters in Nancy (3), Lyon, Grenoble
  - GPU-level reservations
  - IPv6
  - ARM servers
- 30 regression tests (1161 configurations) to ensure that everything works consistently

Key numbers: users and publications

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Active users	564	553	592	514	528	458	573	600	564
Publications	154	141	101	134	106	143	122	151	127
PhD & HDR	14	20	9	27	24	30	27	23	22
Usage rate	50%	56%	58%	63%	63%	63%	55%	53%	70%

- 1313 active users over the last 3 years
- 3769 active users since 2003
- 2007 publications that benefited from Grid'5000 in our **HAL collection**[4]
  - Computer Science: 96%, Mathematics: 2.4%, Physics: 2.4%
  - Since 2015: LORIA: 23%, IRISA: 23%, LIG: 19%, LIP: 13%, LS2N: 13%, CRISTAL: 5%, LIRMM: 5%, LIP6: 3%

[4] https://hal.archives-ouvertes.fr/GRID5000

Grid'5000 organization and governance

Groupement d'Intérêt Scientifique (GIS)

- **Director** – Frédéric Desprez
- ***Bureau*** (6 members: FD, LN, Christian Perez, Adrien Lebre, Laurent Lefevre, David Margery)
- ***Comité des responsables de sites***
- **Technical Director** – Lucas Nussbaum
  - Technical team (8.2 FTE)
- **Architects committee** (6 members)
- ***Conseil de groupement***
  - Inria, CNRS, RENATER, CEA, CPU, CDEFI, IMT ($\approx$ Allistène + RENATER)
- ***Conseil scientifique***
  - 10 international members

institutional and scientific steering

technical steering

advisory and evaluation bodies

Technical organization

- Distributed infrastructure, but managed by a single distributed team
  - Strong coherence and coordination between sites
- Current composition: 8.2 full-time engineers
  - Inria: 5.91 (perm: 0.86, CDD: 5.1), CNRS: 1.02 (perm: 1.02), U. Rennes: 0.6 (perm: 0.6), IMT Atlantique: 0.4 (CDD: 0.4), U. Lorraine: 0.2 (perm: 0.2)
  - Including Pierre Neyron: Médaille de Cristal du CNRS 2019

Conclusions

- An advanced and established infrastructure for the *data-center* facets of Computer Science
  - Large-scale, distributed
  - Shared (many involved laboratories and institutions)
  - Designed for reconfigurability, observability, reproducible research
- Looking forward to extend this scope through collaborations in the context of SILECS
  - Compared with FIT: we share the same design goals, principles, but focus on different objects
    - *Core* of the Internet vs *Edge* of the Internet
    - *Internet of servers* vs *Internet of clients*
  - Strong needs of joint experiments